Cooperative Agreement
University of Montana

FINAL REPORT FOR RESEARCH AGREEMENT
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"Natural Succession Following a Stand-Replacing Blowdown Event in the Aquarius Research Natural Area"
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Aquarius RNA Windthrow Succession Study Final Report

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Summary

A naturally occurring 17 hectare microburst windthrow event in the Aquarius RNA was studied during the summers of 1997-1999. Background information on stand history, structure, and vegetation patterns was collected in addition to the establishment of permanent plots within the windthrow area. Analysis of plot data and aerial photos in the area suggest that the windthrow created a complex disturbance mosaic. Both wind-snapped and root-thrown trees are common in study area. Recovery of biodiversity and forest structure appears rapid, but distinctive from other disturbance types. Further work is needed to fully understand the long-term implications of wind and its interactions with other disturbance events. It appears that the rainforest environment of this site may have enhanced the significance of this event, since fire is relatively infrequent and many of the species present are well adapted to this kind of disturbance.

Introduction

In the eastern United States windthrow has been found to be a significant natural disturbance agent (Canham 1984; Foster 1988; Foster & Boose 1992). In the Pacific Northwest and Alaska wind is also recognized as a major disturbance factor. It is associated with more diverse stand structures and understory plants than catastrophic fire or logging (Alaback 1995; Veblen & Alaback 1995; Price et al. 1998) In these other regions, windthrow is generally thought to have unique ecological consequences for succession, stand development, and nutrient cycling. This is because, particularly in contrast to fire, disturbance occurs from the top down rather than from the bottom up, resulting in a irregular thinning or clearing and less uniform ground damage. In cool coastal environments this irregularity in the forest floor leads to more diverse microhabitats and an increase in nutrient availability (Bormann et al. 1995).

Little information is available on the ecological effects of windthrow in the northern Rocky Mountains region. Microburst events, where intense wind storms flatten a relatively small area of forest, have been reported throughout the northern Rockies region, but few published studies are

available on their ecological implications. Of particular interest are the implications of windthrow to stand development and plant succession as compared to other disturbances in wet micro-environments within this region, where their effects may be the most profound.

In this study we wished to document in detail the effects of one such microburst event in a unique coastal rainforest-like environment in northern Idaho (Alaback et al. In press).

Objectives

1. Document initial effects of windthrow on vegetation patterns in study area
2. Document stand structure of mature forests in vicinity to better establish the pre-disturbance condition of forests in the study area.
3. Document treefall patterns in disturbed area.
4. Document residual trees and their characteristics

Methods

Study site

The Aquarius RNA is located in the North Fork of the Clearwater River Basin in northern Idaho. This is a climatically unique area with mild temperatures and higher rainfall than in most surrounding areas. Mean annual precipitation (1965-1970) is 1095mm and mean annual temperature is 9.1 °C[1]. The study area is also quite low in elevation (1,800-2,400 ft, or 548 to 732m), again somewhat unique in this region. The site also falls on a north-facing slope, accentuating the high levels of moisture in the area. While much of the northern Rockies in general is semi-arid and dominated by fire tolerant slow growing conifer forests at elevations greater than 1000m this area represents a wet mild enclave often described as a disjunct coastal rainforest environment. These factors in addition to corresponding historical ones have given rise to an extraordinarily rich, productive and unique flora in the region (Johnson & Steele 1978; Cooper et al. 1991; Alaback et al. In press).

[1]USDI National Park Service. 1987. Unpublished. National Natural Landmark Evaluation: Aquarius Research Natural Area (Idaho).

Vegetation response to windthrow

For assessing the effects of the microburst on vegetation dynamics we established six transects across the windthrow site. Each transect was 30 meters long, proceeded from east to west and crossed the slope at the upper, middle, and lower portions of the unit, as delimited from our photo analysis. Labeled (with grease pencil and flagging) wooden stakes were placed at each 1-m^2 plot center, and rebar were placed at the end of each transect to aid future remeasurements. Microplots were laid out by putting the first plot center at the beginning of the transect 50cm to the left (90°) then locating the next plot 2m up the transect and to the right (90°) and so on (see figure 1). A meter stick was used to delimit the outer boundaries of each circular microplot. Each transect consists of 15 1-m^2 plots within which we estimate cover classes for all plant species, exposed soil, rock and tree seedlings (less than DBH in height) (Daubenmire 1959). The 30m transect was also used as a line intercept for assessing the abundance of coarse woody debris (over 10 cm in diameter). Each piece encountered was measured for the estimation of surface area and volume as well as orientation and decay class. Locations of pieces were also recorded so that patterns in coarse woody debris abundance could be related to individual plot data. In addition we tallied all tree seedlings (less than DBH height) by species and height class in a 5m wide belt transect.

Plant species which we could not reliably identify in the field were sampled for later analysis. Plants were pressed, dried and cataloged. Those plants in flower or fruit were keyed out using Hitchcock and Chronquist (1973). Identification of specimens were then verified[1] .

[1]Peter Stickney, (retired) USDA Forest Service, Rocky Mountain Res. Sta., Missoula, MT.

Historical and stand structural analysis

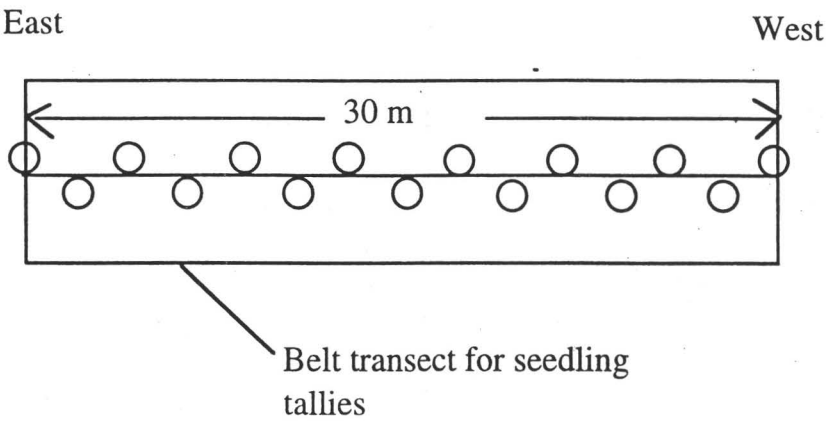

Figure 1. Microplot layout for vegetation monitoring in the recent windthrow portion of the RNA.

To assess the historical influence of wind and other disturbances in the area we also established 11 0.076 ha stand structure plots. We used stand exam information provided by the North Fork Ranger District to determine what were the stand composition and structural types prior to the windthrow event (we also had aerial photos taken just before the windthrow). We then used contemporary photos to determine where we could locate plots that would best represent these types on each side of the windthrow. Each of these plots were established along the same azimuth as the transects and were marked within forest stands adjacent to the windthrow area(Fig. 2)

A core circular plot of 380 m^2 was used to estimate abundance of both live and dead trees. Plot centers were numbered and marked with wooden stakes and flagging. Fiberglass tapes were used to delineate four sides of the plot. General plot information including aspect, elevation, slope, habitat type, and canopy structure were recorded. Tree species and diameter measurements were taken for all trees over 2 cm in diameter and those over 10cm tagged for remeasurement. In

addition, height, crown ratio, and age samples were taken for representative dominant and/or codominant trees. Increment cores were stored and transported in plastic straws for later laboratory analysis. Lastly, a circular 760 m^2 plot was established from the 380 m^2 plot center to tag and inventory trees over 30 cm in diameter using the same procedures as in the smaller plot. Any evidence of disturbance, such as fire scars or root throw mounds were recorded over the entire plot. We also noted any trees that appeared to be of nurselog origin, which might provide further evidence of windthrow history. All coarse woody debris greater than 10cm in diameter and greater than 2m in length was tallied in the 760 m^2 plot. Information on length, orientation, small and large diameters, and decay class was also recorded.

Photo analysis

A series of oblique photos was taken the first summer after the microburst event by consultant Richard Walker (July, 1995). Photos were taken at a low elevation so that greater detail in individual trees would be available (180m above ground, so that each photo covers 1.1 ha). These photos were examined in order to form some general impressions of the site. Because these photos had considerable distortion due to the low elevation and the oblique angle of the camera, we had to define true area polygons for doing our tallies. Four polygons within the windthrow representing the lower, middle, and upper portions of the disturbance were defined by landmarks at the edges of the windthrow (fig 2). On a standard horizontal USFS photo, the windthrow area was enlarged approximately 3.5 times, subsequently each of the 4 polygons was drawn using the same landmarks that were visible on the oblique photos. These polygons were judged to more closely represent the true area of each polygon. The area of each polygon was then estimated using image analysis software after scanning the images.

To document residual trees, diameters and heights were measured to the nearest 0.001" with dial calipers of all residual trees in each of the four polygons. As a general index of tree size, each tree was measured with respect to height, crown ratio, diameter, and species. To document windfall

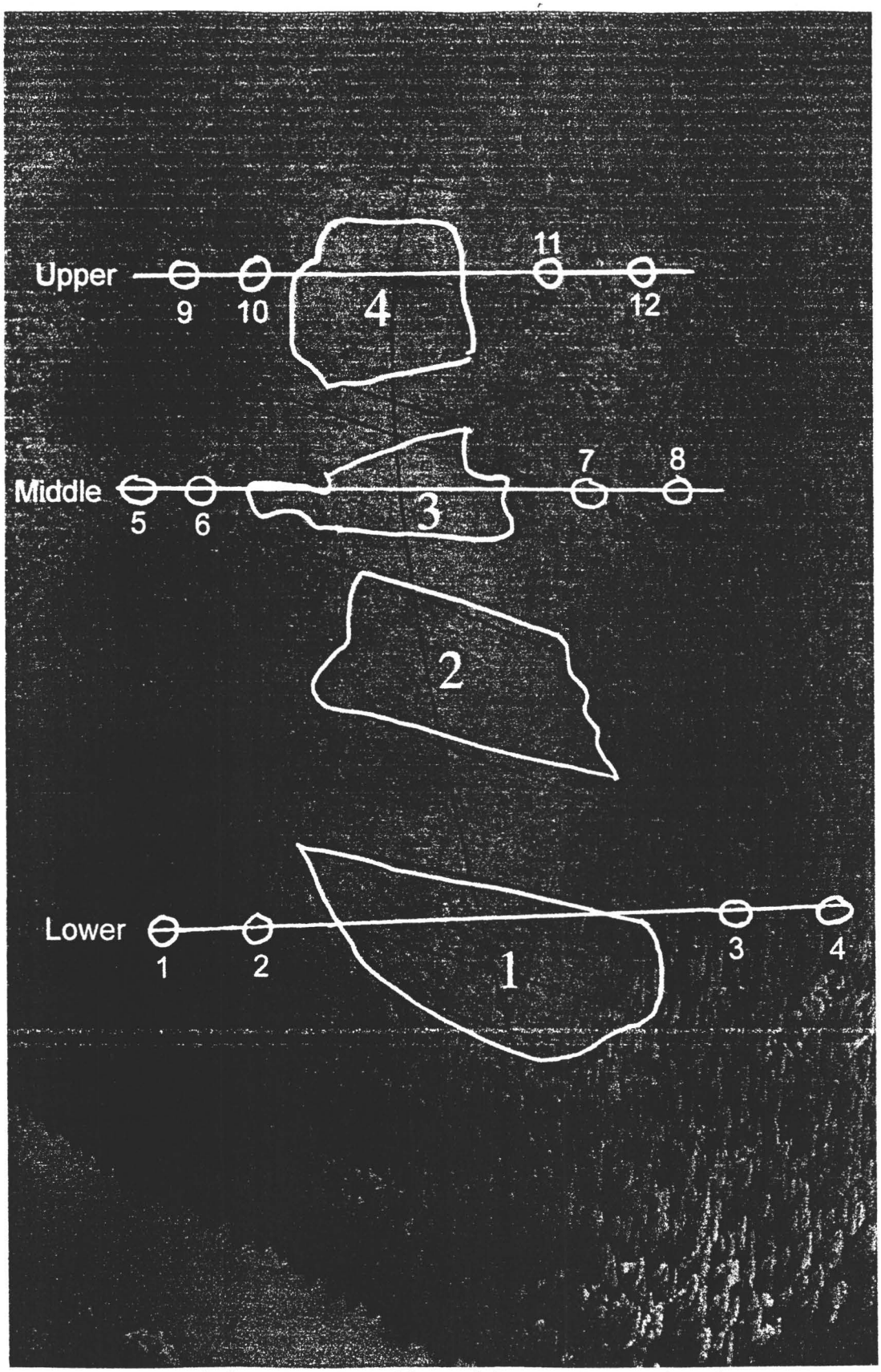

Figure 2. Location of windthrow & layout of vegetation plots.

patterns, the same 4 polygons were used. In each polygon all snags and downed material were tallied by species and by diameter class (measured with calipers). Each piece was also classified as snag (standing dead, usually with broken top), tip-up (obvious root throw mound created), or log (tree downed but with no obvious tip-up mound). Average direction of logs was also noted in this analysis.

Results and Discussion

Vegetation patterns

The Aquarius area is renowned for its high species diversity and endemism[1] [2](Johnson and Steele 1978; Lorain 1988). Our preliminary data also suggests the high diversity of this area immediately following the windthrow disturbance (Table 1). Over 100 species of vascular plants were found in our sample plots. In the windthrow 88 species were found (45 unique to the windthrow) and 56 in the mature forests (only 13 unique). The species encountered suggest a cool wet or even riparian site (Daubenmire 1952; Cooper et al. 1991). For example nearly half the plots had the maidenhair fern, *Adiantum pedatum.* Other species suggesting a wet site include a high abundance of *Festuca subulata*, *Carex* spp., *Mitella stauropetala,* and *Montia siberica* . Relatively few of the species were widespread disturbance-dependent species such as *Rubus spp.,* and *Epilobium spp.*

Table 1. Number of species by lifeform in mature and wind thrown plots

SITE	TREE SEEDLINGS	SHRUBS	GRAMINOIDS	FERNS	FORBS	TOTAL
Windthrow	4	18	12	10	44	88
Mature	1	16	5	12	22	56

[1]Plants of the Aquarius Research Natural Area. Unpublished list compiled by USDA Forest Service, Clearwater National Forest, North Fork District. Dated September 12, 1995. A compilation of published and unpublished sources.

[2]Lichthardt,J.J. 1992. Monitoring of sensitive plant populations in Aquarius Research Natural Area, Clearwater National Forest: second year data. Unpubl. report on file at: Idaho Department of Fish and Game, Boise, Idaho. 14 pp.

Biodiversity was very high in the windthrow, just 5 years after the disturbance. Species richness ranged from 40 to over 50 in 0.04 ha mature forest plots, among the highest recorded for temperate forests. Windthrow plots in total had an even larger species pool (88 species) and equal areas of sampling suggested much higher average richness than in the mature forest. It appears that windthrow allowed for the survival of most plant species while also providing for invading species with higher light requirements. While this also occurs in post-fire succession, with windthrow, biodiversity appears to recover even more quickly (Stickney 1986). In terms of dominance (Simpson's diversity index) mature forests had consistently high diversity whereas the windthrow had much more variation (Figure 3). In the windthrow, a few species such as *Rubus parviflorus* , *Galium aparine*, or *Cirsium vulgare* often dominated vegetation plots. In other plots, there was a more equitable distribution of plant cover by plot.

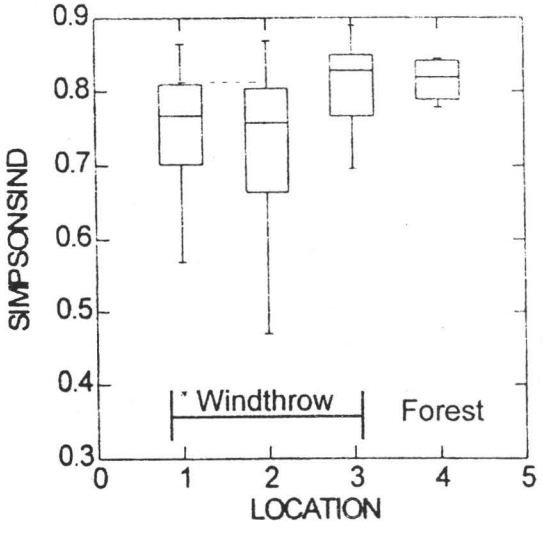

Fig. 3. Equitability as measured by Simpson's index near the windthrow at Aquarius RNA, Idaho. Locations 1-3 were in the recent windthrow, 4 is the average of plots in the adjacent mature forest.

The windthrow had several key effects on vegetation patterns in the area. The mature forests were dominated by ferns and forbs. In the windthrow there appeared to be a more equal distribution of cover across a wide range of lifeforms. Alder and bramble species (*Alnus* spp. and *Rubus* spp.)

were particularly responsive to the windthrow event. Some forbs, such as *Cornus canadensis*, *Coptis occidentalis* and the weedy *Galium aparine* also significantly increased their abundance in the windthrow. Wind dispersed species in general were more likely to colonize the windthrow than fruiting species (which mostly persisted from the original forest).

The windthrow also had an important effect on tree establishment. In this area with high rainfall and dense forests, tree regeneration generally requires disturbance. Regeneration failures are common following other disturbance types. In this windthrow site, it was difficult to see regeneration because of all of the windthrow debris and dense vegetation. Despite this we found significant regeneration of the dominant species, grand fir (*Abies grandis*) throughout the area and also found seedlings of disturbance dependent conifer species (Table 2). Grand fir is the only species that would be judged adequately regenerating from a silvicultural point of view (>250 seedlings/ha 30cm or more tall). Much of the grand fir regeneration seemed associated with residual alder trees.

Table 2. Tree seedling regeneration density per hectare in recent windthrow at Aquarius RNA. Tallies based on 150m^2 sampling area along each transect. Numbers in parentheses are seedlings greater than 30cm tall.

Location	*Abies*	*Pseudotsuga*	*Pinus*	*Thuja*
Upper	1,133(333)	133		
Middle	400(133)	67		67
Lower	1,866(400)	267(133)	200(67)	
Average (>30cm):	289	44	22	

Stand structure analysis

General tree distributional patterns

We found little evidence of even-aged historic windthrow origin forests near the recent windthrow area. We did not see unusually prominent windthrow mounds or stand structures that suggested historic events. Few tip-up mounds were found in our stand structure plots. Fire scars were also rare, but this may be more due to dominance by grand fir which generally does not scar in the presence of fire. No trees were found which survived the holocaustic fires of 1910 (Fig 4). Some trees were also killed by more localized fires in 1935[1]. Interestingly, analysis of coarse woody debris shows that much of the area originally had significant coverage of cedar (*Thuja plicata*) but living trees are mostly grand fir, red alder (*Alnus rubra*) , western larch (*Larix occidentalis*), and Douglas fir (*Pseudotsuga menziesii*).

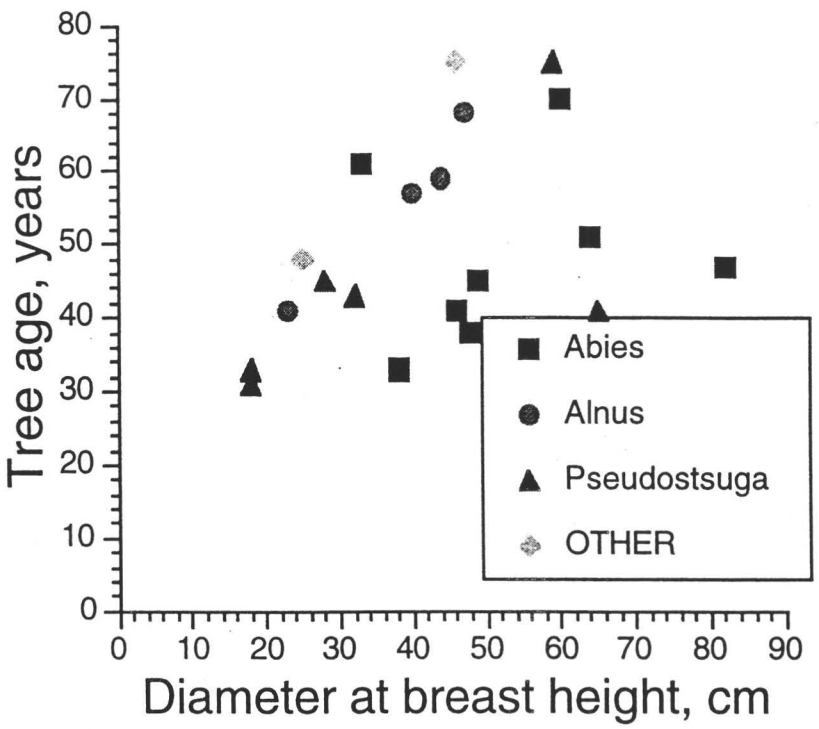

Figure 4. Ages of representative trees within mature forests of Aquarius RNA. Data derived from increment core analysis in the lab.

[1]Barrett, S. W. (1982). Unpubl. Report. Fire's influence on ecosystems of the Clearwater National Forest: Cook Mountain fire history inventory. USDA Forest Service, Clearwater National Forest, Fire Managment. 42 pp. plus appen.

After having done extensive on-the-ground reconnaissance in the area it is clear there are several significant vegetation patterns in the area. At the upper end of the windthrow the forest is more montane in character with occasional mountain hemlock (*Tsuga mertensiana*), grand fir and alder. The area is dominated by geologically unstable slopes with many steep slopes and flat benches below. The flat benches are generally dominated by a mixture of red alder and grand fir. The steep slopes are generally dominated by grand fir, and in extremely well drained slopes, by Douglas-fir. One western hemlock (*Tsuga heterophylla*) seedling was found in our lowest plot, near the river. One mature individual was also found near the Aquarius campground. There was much evidence of *Betuala papyrifera* being common in the forest (coarse woody debris) but only a few living trees were found in our plots. Although the windthrow may have accelerated this process slightly, it is clear that this early successional species has been succeeded by more shade tolerant conifers (e.g. grand fir) following the slow post-fire succession from the 1910 fires.

In examining photos before the windthrow and immediately after the event there is little evidence of the windthrow following forest cover type boundaries. The windthrow mostly crossed two stands that were delineated for stand exam inventory. The windthrow also included small portions of three additional stands. According to USFS stand exams, original stand condition included mature forests of grand fir, Douglas-fir, and larch with some inclusions of western redcedar and some significant pockets of red alder in the upper portion of the windthrow (especially prominent from aerial photos).

Extensive alder intrusions in the center of the windthrow and to the east of the windthrow did not seem to influence windthrow boundaries. We conclude that the windthrow was influenced more by local topography (Thompson Point for example) than forest type or soils moisture conditions. In addition to this narrow windthrow disturbance, windthrow pockets were created along the south

side of the river all the way east to the Aquarius campground, and in patches on the adjacent south-facing slope, all in the same storm in 1994.

Table 3. Estimates of tree size and composition in windthrow from tallies of recent[1] downed logs, Aquarius RNA. Tallies represent logs >10cm/ha in 150m^2 belt transects..

Diameter, cm	Upper	Middle	Lower	Average
10-19		67		22
20-29			67	22
>29		134	201	112
Totals	-	201	268	156

Tree diameters and densities

In the windthrow site surveys of coarse woody debris provide an approximate picture of the stature and composition of the original forest (Table 3). Since the tallies only included 150 m^2 of sampling in each area, they best represent smaller and more frequent tree size classes. All transects had grand fir logs, suggesting this was the dominant species in the area. The upper and middle transects also included red alder and paper birch. The lower transect also included western white pine (*Pinus monticola*).

[1] decay class 1 and 2 (little evidence of stem decay or bark loss).

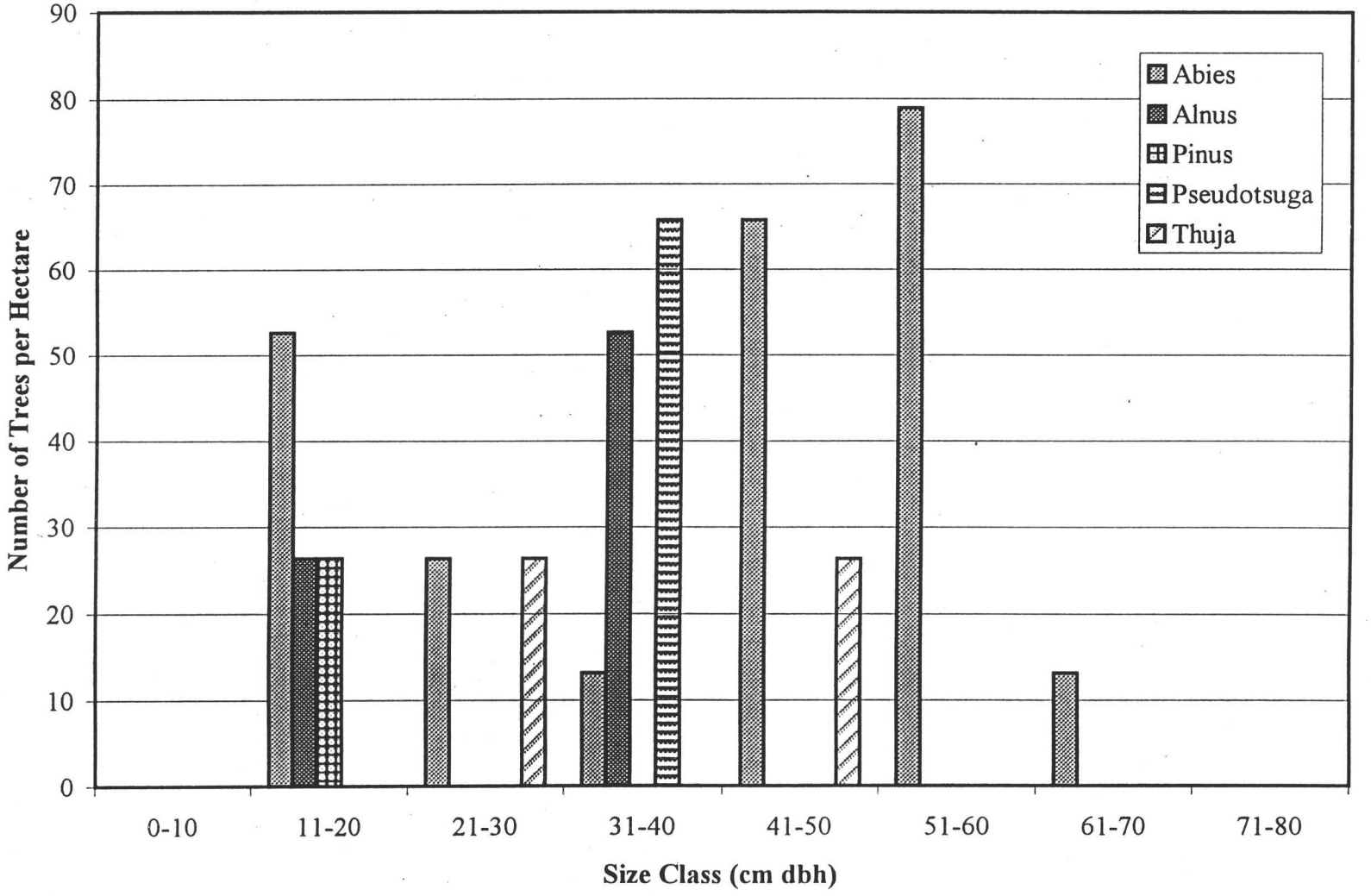

Figure 5 - Size class distribution of trees in stand plot 4 (.076 ha).

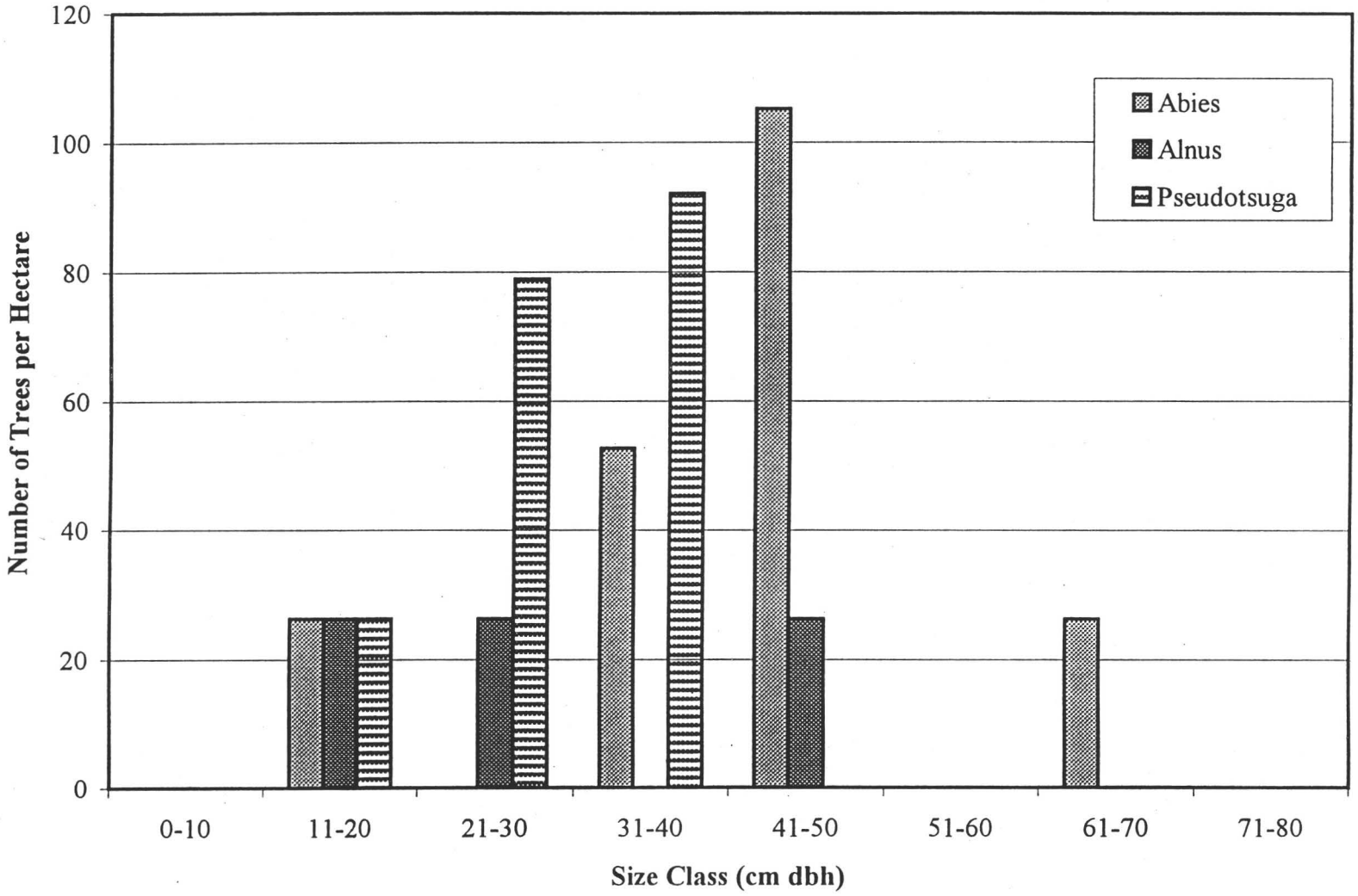

Figure 6 - Size class distribution of trees in stand plot 6 (.076 ha).

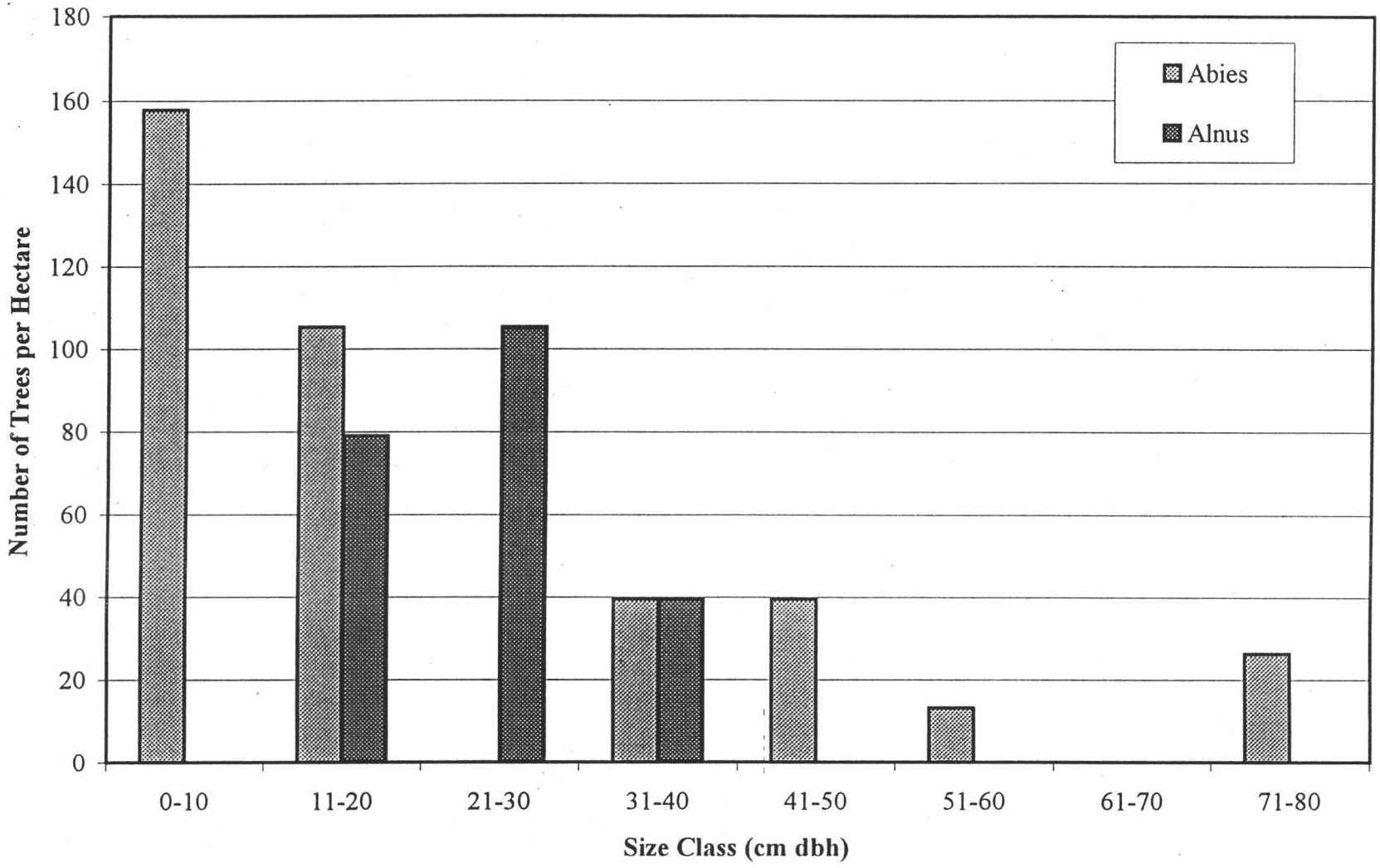

Figure 7 - Size class distribution of trees in stand plot 12 (.076 ha).

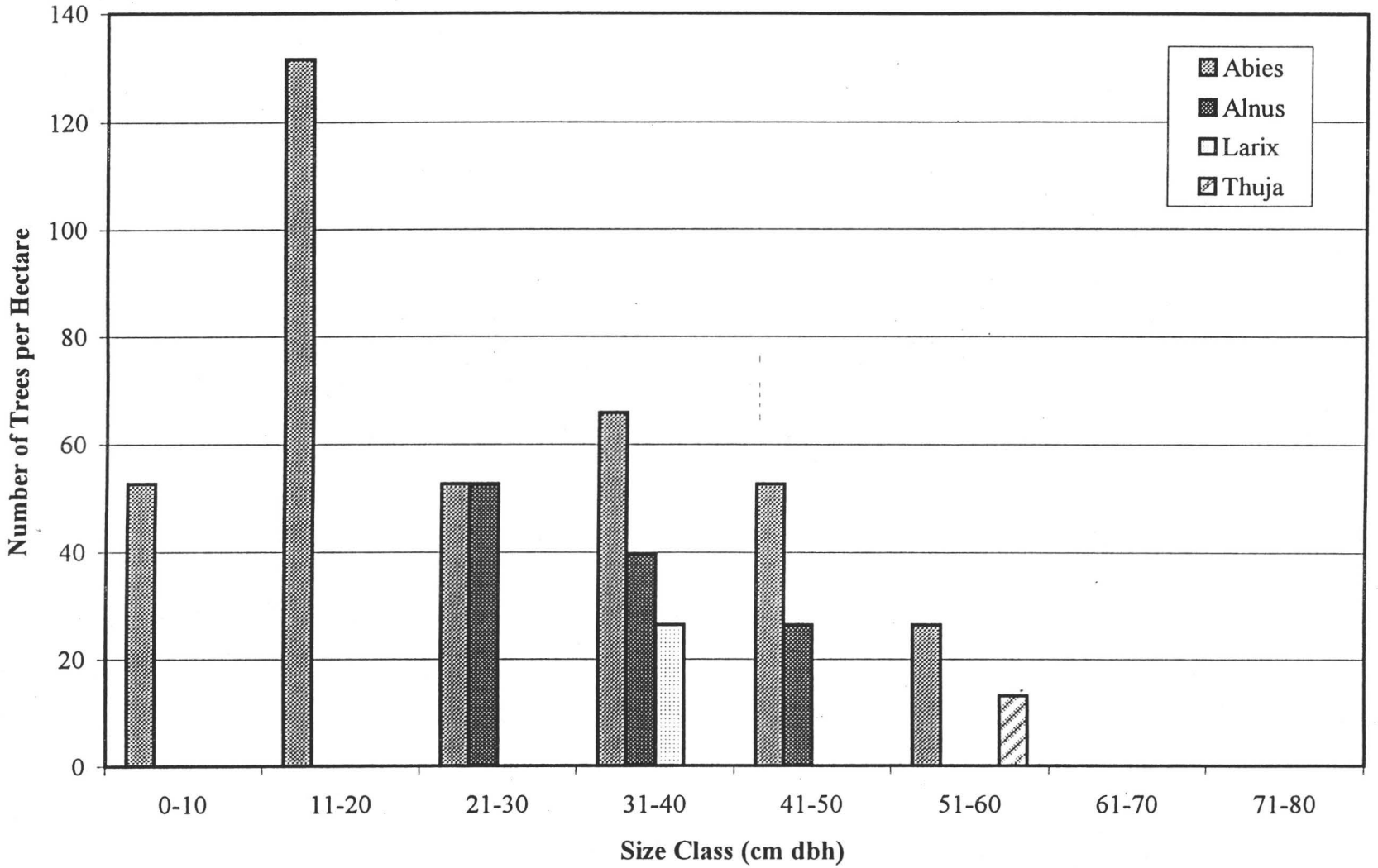

Figure 8 - Size class distribution of trees in stand plot 1 (.076 ha).

Table 4. Basal area, m^2/ha by species in 0.076 ha permanent plots in Aquarius RNA.

Plot	*Abies*	*Alnus*	*Larix*	*Pinus*	*Pseudotsuga*	*Thuja*	Total
1	26.7	10.9	2.6			3.2	43.4
4	33.5	5.7		0.5	6.5	5.6	51.8
6	22.9	6.1			13.7		42.6
12	15.9	10.8					26.6
Total	24.7	8.4	0.7	0.1	5.0	2.2	41.1

Sampling of mature forest plots on each side of the windthrow provide a more complete picture of stand structure in the area and a reasonable surrogate for stand conditions prior to the windthrow event, since stand exams and photos before the windthrow do not suggest any consistent differences between these areas. Four representative stands are presented in figures 4-7. 5-8 Structure is typical of seral fire-origin stands in this productive habitat type (*Abies grandis/Asarum caudatum*). Dominant trees were generally 60-80 years old and 30-70cm in diameter at breast height. Grand fir was generally the only species able to regenerate in these dense forests as evidenced by trees less than 20cm in diameter. Douglas-fir and western redcedar generally occupied middle to upper diameter classes, suggesting their regeneration only after the fires of 1910 and 1935 or other significant disturbances. In alder dominated stands, there was little recent regeneration, although it generally was well represented in middle diameter classes. Our analyses of stand structure plots suggests alder was widespread in the area, not just in the pockets visible on the aerial photos. Stands were generally somewhat patchy mostly as a function of irregular topography owing to its unstable geology (Steele 1971). Larch was scattered in plots only up to the middle transect. All the other species were generally found at all elevations. The general abundance of each species is best summarized by the basal area data (Table 4). Clearly grand fir and alder are the dominant species in the study area. In some cases grand fir had truely exceptional

growth for the Rocky Mountain region, such as the trees sampled scarcely 50 years old, yet 70-80 cm in diameter (Fig 4).

Photo analysis

Initial examination of the photos led us to divide the site into three distinct zones: root throw was prevalent at the bottom of the slope, there were many bole-snapped trees in the middle portion of the site, and there were a number of standing live trees at the top of the site. In windthrow ecology, these types of wind-caused mortality are key to distinguish between since they imply different types of wind-stress and ecological responses. For example on the Pacific coast, windsnap is the prevalent mortality type, mostly due to the widespread extent of stem rot and root rots in mature trees (Veblen and Alaback 1995). Only right along the coast where forests are subject to high speed winds does root throw or tip-up mounds become more prevalent. Hardwood forests generally have more incidence of tip up mounds than conifer, but it is not clear why this is. With tip-up mounds, soils disturbance is more significant, leading to more important changes in nutrient availability and plant regeneration response (e.g. Bormann et al., 1995).

Table 5. Forms of wind-caused mortality in 1994 storm for trees in Aquarius RNA.

	Relative density of coarse woody debris			
Polygon (lower)	Tipups	%	Snags	Stem snap
1	4	9%	15	41
2	4	10%	5	34
3	2	24%	1	7
4 (upper)	2	4%	5	41

In Aquarius both stem snap and root throw (tip up mounds) were common, but varied according to location within the windthrow area. At the top of the windthrow near the top of the ridge and at the bottom of the slope on a flat bench stem snap was the most common (41%). At the top of the slope most logs fell straight down the steep slope (to the north); on all other polygons trees

generally fell to the west (presumably the direction of the winds). The highest incidence of tipup mounds (24%) was in the wet hummocky alder bench near the middle of the windthrow. Perhaps the soil moisture and the openness of this forest made it more susceptible or simply alder as a hardwood is more prone to this form of windstress. Very few small trees developed tipup mounds, so a threshold tree size may be necessary as well.

Snags were also striking in abundance following the windthrow event. Since they had little wind "fetch" or resistance to flow even if relatively frail they still survived the windthrow relatively well. They varied widely in size but the larger size classes were generally more common. Thus from a wildlife habitat standpoint the windthrow may have provided an enhancement to habitat. Vegetation biodiversity, and abundance of berries were stimulated while a high density of snags were maintained.

Table 6. Relative density of residual trees after catastrophic windthrow event in Aquarius RNA.

Polygon (upper)	*Abies*	*Larix*	*Alnus*	*Acer*	*Thuja*
4	5.3	0.5	0.8	1.0	0.0
3	2.6	2.2	0.9	0.1	0.0
2	2.0	1.4	1.5	0.0	0.3
1 (lower)	5.3	1.9	0.3	0.0	0.2

The final question of this study was the extent to which the windthrow changed the trajectory of stand development by influencing the species or size of residual tree. It is generally thought that *Larix* especially when storms occur in winter should survive more readily than other species in the region, just because of less wind fetch (deciduous) and high root strength. Certainly *Larix* fared well after the windthrow, with a much higher percentage of residual trees than in the original forest (e.g. see table 4). *Thuja* also appeared to weather this event well, since it was relatively rare in the

pre-windthrow forest. Alder seemed to generally resist the windthrow well and also has the advantage of rapid epicormic branching. Despite all of the above it is important to point out that grand fir still was the most common residual tree in the area. Clearly grand fir dominated the original forest as it does all the surrounding forest today despite its predilection for stem rots and often a massive canopy.

Conclusions and recommendations for further study

The massive windthrow event that leveled nearly 17 hectares of mature forest in the Aquarius RNA in 1994 has produced a complex ecological disturbance. This ecosystem appears to be responding very differently than it would from other types of catastrophic disturbance. Wind, like fire is highly variable in its impacts on the ground. It varies with topography and with the dynamics of wind flow itself. The naturally hummocky terrain in this study site also appeared to contribute to the variable responses of trees to this severe wind stress. The form of wind-caused mortality is a complex integration of many physical and biological factors in this site resulting in tip-up mounds, or stem snap depending on where you are in the site.

This extraordinarily species rich ecosystem has retained or even enhanced its biodiversity within 5 years of the windthrow event. Endemic and unique species appear to be faring well with this disturbance event. Natural regeneration of trees also appears to be adequate, especially for grand fir. It thus appears that on the one hand this was a unique event. We were unable to find any naturally occurring stands in the area that suggested a similar event in the past. However, this interior rainforest appears to be well adapted to recovery following this disturbance, at least in its initial stages.

Forest succession is a long-term process. Indeed, the mature forests around the windthrow and the forest before the windthrow showed ample evidence of continuing changes following the catastrophic fires of 1910. To fully understand the implications of this disturbance, further

monitoring is needed of this site and of several others in the region. We recommend that the windthrow area be remeasured five years hence. With 10 years of remeasurement information, this succession could be more effectively compared with long-term studies already completed following logging and fire in the region.

Windthrow is an important natural phenomenon in the conifer forests of the northern Rockies. Microbursts such as what occurred in Aquarius are striking and hard to miss. But chronic windthrow is common in this region as well. If we are to successfully implement ecosystem management especially in regions with high levels of endemism and biodiversity it will be necessary to understand not only the dominant disturbance agents such as fire but also complex disturbance agents such as wind. In these ancient landscapes it is likely that the interactions of these many agents will provide a much richer set of explainations of the patterns we see in forests especially at the landscape scale where the patterns we have described appear to be the most prominant. In rainforest environments in the Rockies, as in the coast, wind may be a key ecological factor to consider in explaining forest and landscape structure.

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